



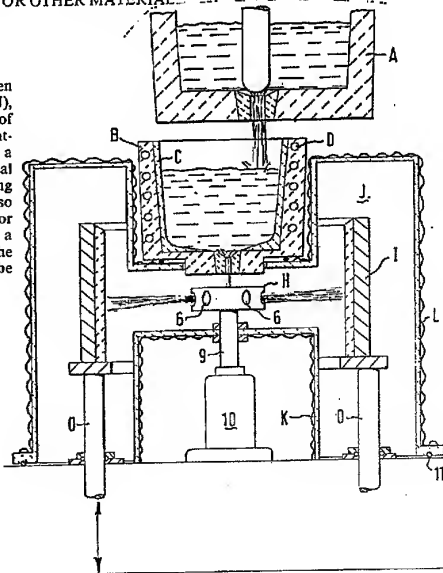
## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(54) Title: APPARATUS FOR SPRAYING METAL OR OTHER MATERIAL

## (57) Abstract

Apparatus, for the centrifugal spraying of molten metal or other material, comprises a closed chamber (J), means for controlling the temperature and pressure of the atmosphere in the chamber, a spraying rotor mounted on a vertical axis in the chamber and comprising a positive impeller (H) having a central eye and radial vanes, a wall (I) in the chamber coaxially surrounding the impeller in the path of spray from the impeller, so as to receive the sprayed molten material, means (O) for reciprocating the wall relatively to the impeller, and a tundish (B), having heating means, mounted above the impeller and arranged to feed molten material to the eye of the impeller.



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APPARATUS FOR SPRAYING METAL OR OTHER MATERIAL

This invention relates to apparatus for centrifugal spraying of molten metal or other material either to effect spray deposition on to a mould or to produce powder.

Centrifugal spray deposition can be used to atomise liquid metal into droplets and propel them at high velocity to "splat" against a mould surface and build up a solidified metal form.

The metallic structure of the deposited metal is a homogenous mass, resulting from splatted particles becoming intimately united, of which the density, grain size and other characteristics can be controlled by selection of the operating conditions of temperature, thermal conductivity and thermal capacity of the surfaces contacted by the metal, ambient atmospheric conditions, effective velocity of the centrifuge and the flight path and distribution of the metal droplets.

For bulk production of metal powder, centrifugally sprayed atomised metal droplets are allowed to fall freely in a cooling atmosphere with or without impingement against a surface in the path of the spray.

It has been proposed (U.S.A. Patent Specification No. 2 307 939 (Merle) U.K. Patent Specification No. 1 517 283 (Singer)) to pour liquid metal on to a horizontal, high-speed rotor disc to effect atomisation, centrifugal spraying and deposition of the metal on to a surrounding mould.

The present invention is concerned with apparatus for the spraying of molten material and, according to the invention, the apparatus comprises a closed chamber, means



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for controlling the atmosphere in the chamber, a spraying rotor mounted on a vertical axis in the chamber and comprising a positive vaned impeller, a wall in the chamber coaxially surrounding the impeller in the path of spray from the impeller, means for moving the wall relatively to the impeller, and a tundish mounted above the impeller and arranged to hold and feed molten material to the impeller.

The functions and further features of the apparatus of the invention are described below with reference, for convenience, to the spraying of molten metal.

The tundish preferably has electrical induction heating coils and may be used for maintaining in a molten state metal poured through the tundish, or for melting metal, and controlling its delivery to the eye of the impeller.

The positive impeller, as compared with a flat dish or shallow bowl as previously proposed, comprises a cup with a refractory lining having an eye in the form of a central well, into which the metal is poured from the tundish, and channels which extend through the refractory lining radially from the central well so that the channel walls form impeller vanes, which may be straight or curved, for positive impulsion of the molten metal.

In the well of the impeller, below the level of the channels, there is a central boss on to which the molten metal impinges, so as to be spread as smoothly as possible, the boss and an overhanging rim provided around the mouth of the well serving to stop splash-back of the molten metal.

The impeller is surrounded by a mould wall, having a relatively rough surface for deposition of the sprayed

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metal, and means are provided, such as hydraulic or pneumatic jacks, for effecting controlled reciprocation of the wall relatively to the impeller, and consequently controlled distribution of metal deposited on the mould wall, so as to achieve uniform or varying thickness deposition. The reciprocation means preferably support and move the mould wall but reciprocation of the rotor is possible. For powder production operation is modified and in particular the mould wall may be replaced by a curtain wall having a polished surface to which the droplets do not firmly adhere so that they form powder particles which drop or can be removed from the wall.

The rotor and mould or curtain wall are enclosed in the chamber provided with means for controlling and monitoring its enclosed atmosphere, usually to ensure an inert or non-oxidising atmosphere for metal spraying, although a reactive atmosphere might be maintained for special purposes.

The chamber is formed by an outer reactor vessel and an inner reactor vessel with insulated and/or cooled walls to effect thermal control, gas-injection connections and pressure-release valves for atmospheric control and sealed access openings for the tundish and the jacks or other reciprocation means.

The outer reactor vessel is provided with positional adjustments, such as by being slidably supported on a base with screw adjusters or other shifting means on intersecting axes, so that the position of the mould, outer vessel and tundish about the rotor axis can be adjusted, usually for centering but possible deliberately eccentric for special purposes, such as variably controlling spray deposition thickness.

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Means may be provided for feeding into the eye of the impeller additional materials as additives to be entrained by the sprayed metal.

The above and other features of the invention will now be described, by way of example, with reference to the accompanying schematic drawings, in which:-

Fig. 1 is a vertical axial section through the major part of the whole apparatus,

Fig. 2 is an axial section of the tundish,

Fig. 3 is an axial section, on a larger scale, of the rotor impeller,

Fig. 4 is an axial section of the chamber vessels showing the atmospheric control connections and positional control means,

Fig. 5 is a fragmentary perspective view of mould wall rotating mechanism, and

Fig. 6 is a fragmentary axial section of an optional feature for introducing an additive to liquid metal to be sprayed.

It is believed that description and understanding are assisted by regarding the apparatus as comprising an assembly of functional modules serving specific purposes and the apparatus will be so described.

#### MODULE 1 - Liquid Metal Supply. Fig. 1

Liquid metal can be provided from an induction, resistance or arc furnace and transported to the spray plant using a bottom pouring ladle A. Alternatively the liquid metal can be poured directly from the supply furnace through a separate launder, or melted within the tundish as described in Module 2.

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MODULE 2 - Liquid Metal Flow Control. Figs. 1 and 2

The liquid metal from the ladle A is discharged into a tundish B which is lined with refractory materials C and surrounded by electrical induction heating coils D designed to maintain the contents of the tundish within controlled temperature limits during spraying. The provision of the induction heating coils also provides the capability to melt small charges of metal within the tundish itself.

Liquid metal flow out of the tundish is controlled by the head E of liquid metal in the tundish and the diameter of the tundish nozzle F subject to the opening of a stopper indicated in broken lines. The nozzle F is constructed from refractory material, preferably of low thermal mass, and is mounted within a refractory casing G.

MODULE 3 - Spray Generation. Figs. 1 and 3

The liquid metal emerges from the tundish nozzle F as a small stream and enters the eye of a rapidly rotating impeller H.

As shown by Fig. 3, the impeller H consists of a steel cup 1, which may be circular or polygonal in plan, and a fitting refractory lining 2 having a central well 3 at the centre of the bottom of which there is a rounded boss 4 on to which the stream of liquid metal impinges so as to spread smoothly outwards. Rotation of the impeller will cause the liquid metal to move radially outwards so that the boss 4 is substantially exposed to the impinging stream.

Above the level of the boss 4, the lining 2 has a regular array of radial channels 5 which extend radially outward, in straight or curved paths, to open through ports 6 in the peripheral wall of the cup 1.

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Around the mouth of the well 3 a refractory ring 7 forms an overhanging rim to stop splash-back of liquid metal from the well.

The base of the cup 1 has a socket 8 for mounting the impeller on the polygonal head of a driving shaft 9 of an electric motor 10 (Fig. 1).

On rotation of the impeller by the motor 10, at a controlled speed, liquid metal poured into the well 3 is spun outwards to enter the channels 5 of which the walls act as impeller vanes ejecting the liquid metal through the ports 6 as an atomised spray of liquid metal droplets. By controlling the rate of pour from the tundish and the speed of the motor 10, the spray can be controlled in quantity and droplet size.

#### MODULE 4 - Atmosphere Control. Figs.1 and 4

Liquid metal droplets leaving the impeller H are projected within an atmosphere of inert gas such as nitrogen, argon or helium, to impact against a mould wall I. The inert atmosphere is maintained in a chamber J between two drum-shaped concentric thermally insulated and water cooled vessels K and L and the purity is monitored prior to and during operation. The rapid increase in inert gas temperature and the consequent increase in gas pressure which accompanies the start of liquid metal spraying is regulated by a combination of water cooling, gas injection through connections M and the inclusion of pressure release valves N at various points on the vessels K and L. (Fig. 4)

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MODULE 5 - Wall Movement. Figs. 1, 4 and 5

Liquid droplets colliding with the mould wall I flatten or "splat" and solidify rapidly. Movement of the wall relative to the droplet spray exposes relatively cool areas of the wall, or of deposited metal, for further splat deposition. Reciprocation of the wall by hydraulic or pneumatic jacks O through the droplet flight path promotes overlapping of deposits and allows a thick homogenous solidified form to be prepared. The heat flux is substantially normal to the wall surface.

For the achievement of a high density within the deposited form, the droplets must remain in a liquid state up to the point of impact on the mould wall.

To promote the formation of contoured deposits the movement of the mould wall can be programmed to provide periods of dwell and rapid acceleration. In other cases the mould itself can be machined to provide a complex pattern for splat casting.

For centering or other positional adjustment, the outer vessel L, which carries the tundish B in a central recess in its closed top, is movable by screwed radial adjusters, at right angles, of which one is shown at S. To facilitate such movement the vessel L has a broad base flange slidable on a supporting sealing ring 11.

Alternatively or in addition to reciprocation, the mould wall may be rotated about the rotor axis. This can be done, as shown in Fig. 5, by providing the mould wall I with a ring gear base flange 12 which rests, by ball bearings 13, on a support ring 14 carried by the jacks O.

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The support ring 14 also carries a bracket 15 on which is mounted a reversible electric motor 16 driving a pinion 17 in mesh with the ring gear of the flange 12. By control of the motor 16, the mould wall I can be rotated as required in either direction about the axis of the rotor.

#### Other Production Techniques

Since the impeller is an efficient mixer the delivery of metal or non-metal additions to the impeller eye in combination with a liquid metal stream from the tundish can result in the manufacture of alloys which are difficult or impossible to produce by other methods.

For example:

- (a) metal or non-metal powders can be dispersed within a metal matrix.
- (b) volatile elements can be added and successfully alloyed with other elements.
- (c) dual phase alloys can be prepared by simultaneously spraying two dissimilar liquid metals or a solid in combination with a liquid.

A typical arrangement is indicated in Fig. 6 in which particles of an additive entrained in a low pressure gas stream are fed to the eye of the impeller H through a pipe P and a ring distributor R through the open centre of which the stream of liquid metal passes.

Deliberate variation of the liquid metal composition passing through the tundish nozzle during a spraying cycle can provide conditions necessary to prepare layered or composite structures. The ability to combine alternate layers of different metals or alloys provides the potential

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of producing for example, corrosion resistant, heat resistant or wear resistant coatings. Alternatively, a composite structure can be prepared by spray deposit of a thin coating of a second component on to the rough as-splatted surface of a previous deposit.

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CLAIMS

1. Apparatus, for the centrifugal spraying of molten material, comprising a closed chamber, means for controlling the atmosphere in the chamber, a spraying rotor mounted on a vertical axis in the chamber and comprising a positive vaned impeller, a wall in the chamber coaxially surrounding the impeller in the path of spray from the impeller, means for moving the wall relatively to the impeller, and a tundish mounted above the impeller and arranged to hold and feed molten material to the impeller.
2. Apparatus according to claim 1, in which the chamber is formed by an outer reactor vessel, having a closed top with a central recess in which the tundish is mounted, and an inner reactor vessel, having a closed top in which the rotor is journaled axially beneath the tundish, the space defined between the outer and inner vessels constituting the chamber.
3. Apparatus according to claim 2, in which the means for controlling the atmosphere in the chamber comprises thermal control walls of the reactor vessels, gas injection connections and pressure-release valves.
4. Apparatus according to claim 1, in which the impeller comprises a cup with a refractory lining having an eye in the form of a central well from which channels extend radially so that the channel walls form impeller vanes.

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5. Apparatus according to claim 4, in which the central well of the refractory lining has a central boss below the level of the channels and an overhanging rim, around the mouth of the well above the level of the channels, to stop splash-back of molten material.

6. Apparatus according to claim 1, in which the means for moving the wall comprise means for vertically adjusting, reciprocating and rotating the wall about the rotor axis.

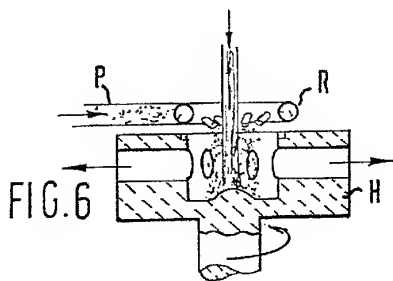
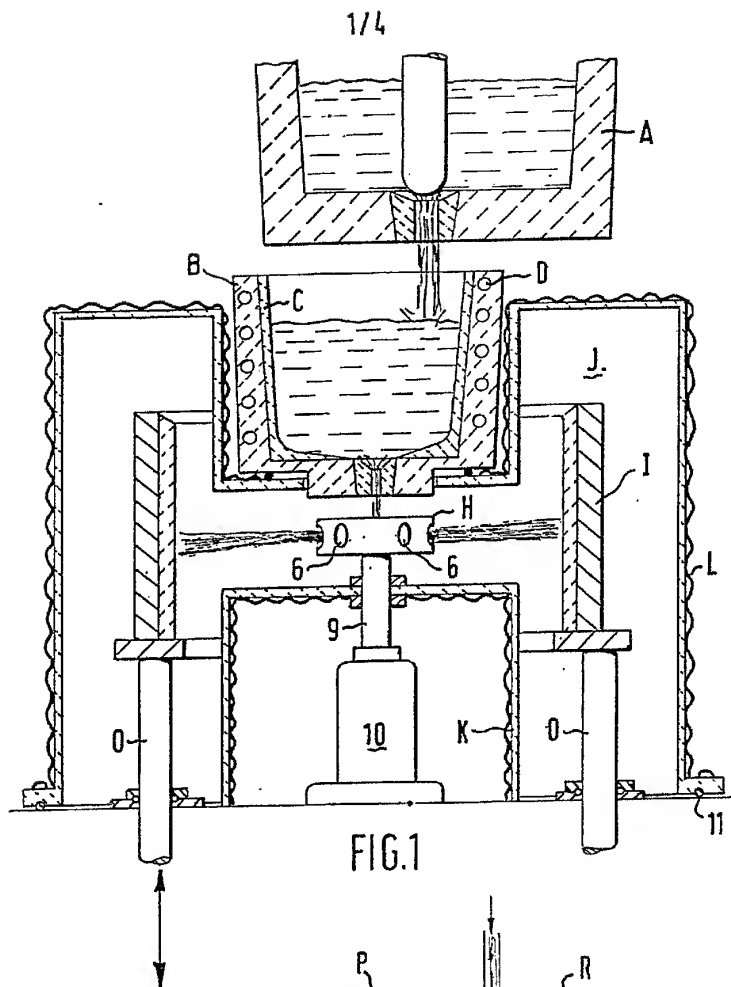
7. Apparatus according to claim 6, in which the wall is a mould wall having a relatively rough surface against which droplets of molten material sprayed on to the wall will splat and firmly adhere.

8. Apparatus according to claim 1, in which the wall has a polished surface against which droplets of molten material sprayed on to the wall will impinge and solidify but not firmly adhere so that solid droplets fall or are removable as powder.

9. Apparatus, for the centrifugal spraying of material, substantially as described and illustrated by the accompanying drawings.

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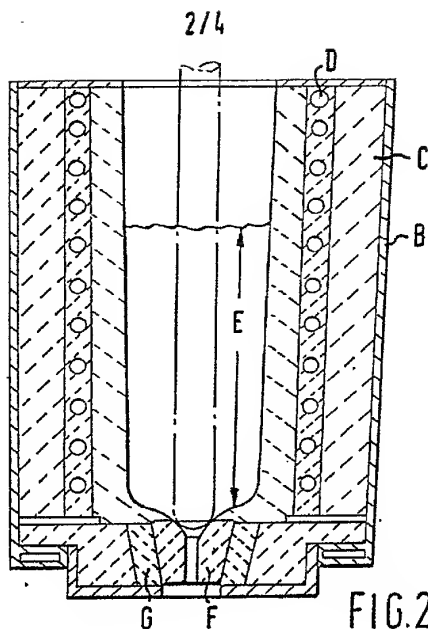


FIG. 2

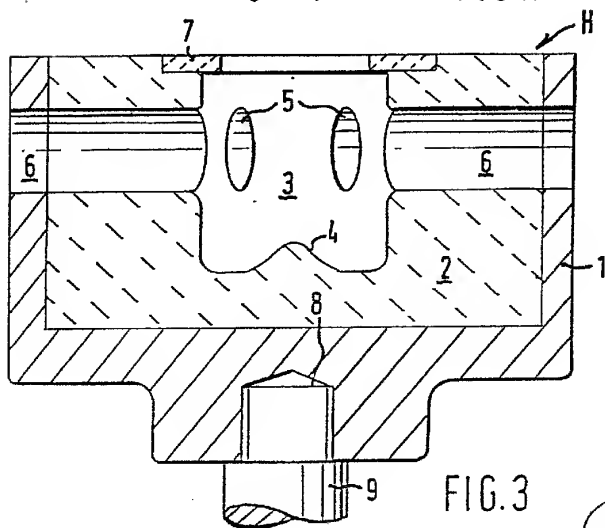


FIG. 3

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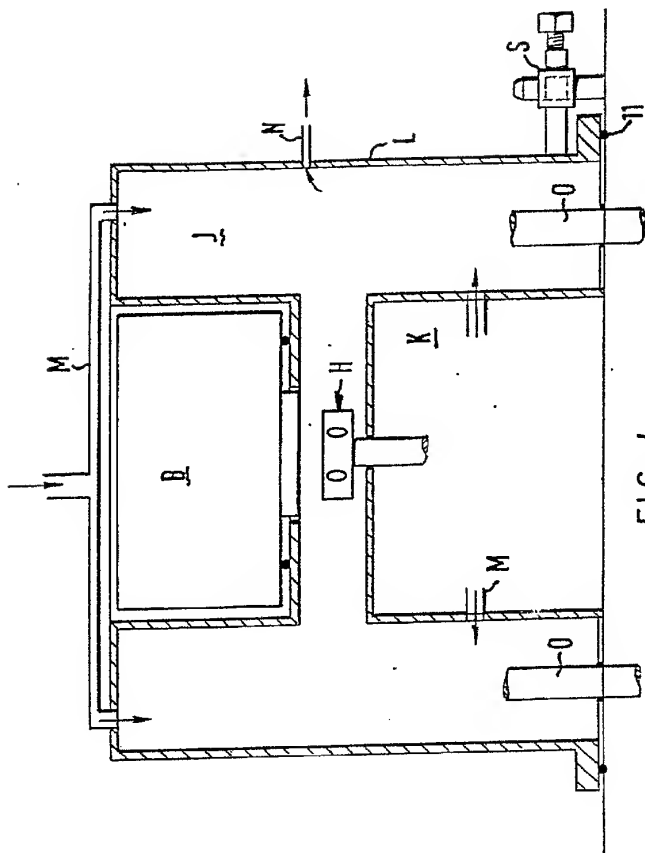


FIG. 4



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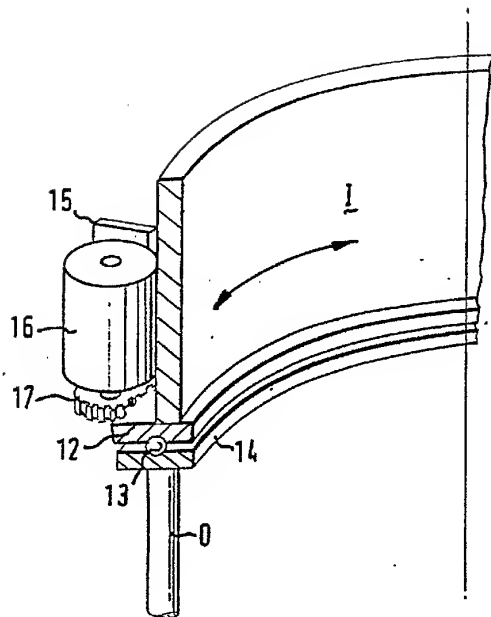


FIG. 5

# INTERNATIONAL SEARCH REPORT

International Application No. PCT/GB 82/00135

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (If several classification symbols apply, indicate all) <sup>3</sup>		
According to International Patent Classification (IPC) or to both National Classification and IPC		
IPC <sup>3</sup> : B 22 F 9/10; B 22 D 13/08		
<b>II. FIELDS SEARCHED</b>		
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Documentation Searched other than Minimum Documentation to the extent that such documents are included in the fields searched <sup>5</sup>		
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT</b> <sup>14</sup>		
Category <sup>6</sup>	Citation of Document, <sup>16</sup> with indication, where appropriate, of the relevant passages <sup>17</sup>	Relevant to Claim No. <sup>18</sup>
X	DE, A, 2308061 (D.J. KLAPHAAR et al.) 22 August 1974, see page 14, line 1 - page 19, line 26; figures 1, 2	1-5, 9
X	DE, A, 1458210 (SCHMIDTHUYSEN) 20 March 1969, see claims 1-4; page 9, line 11 - page 11, line 27; figure 1	1, 2, 4, 5, 9
Y	FR, A, 2276121 (UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND) 23 January 1976, see claims 1, 7, 10, 16, page 10, lines 9-18 & GB, A, 1517283 cited in the application	6, 7
Y	DE, A, 2127563 (BATTELE-INSTITUT) 14 December 1972, see claims 1, 4, 11	8
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July 16, 1982	August 5, 1982	
International Searching Authority <sup>1</sup>	Signature of Authorized Officer <sup>20</sup>	
EUROPEAN PATENT OFFICE	G. L. M. Kruidenberg	



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Reference RD134495/10102	Application No./Patent No. 04253919.7 - 2122
Applicant/Proprietor GENERAL ELECTRIC COMPANY	

#### COMMUNICATION

The European Patent Office herewith transmits as an enclosure the European search report (under R. 44 or R. 45 EPC) for the above-mentioned European patent application.

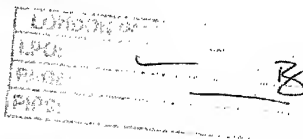
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- ☐ Abstract ☒ Title
- ☒ The abstract was modified by the Search Division and the definitive text is attached to this communication.

The following figure will be published together with the abstract : 1



#### Refund of search fee

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# EUROPEAN SEARCH REPORT

Application Number  
EP 04 25 3919

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	WO 82/03809 A (AURORA STEELS LTD; RICKINSON BERNARD ALAN; KIRK FREDERICK ARTHUR; WYAT) 11 November 1982 (1982-11-11) * page 8, line 6 - line 24 * * page 5, line 15 - page 6, line 11 *	1-10	INV. B22F9/10 B22F3/115 B22D13/08 C22C1/10
A	US 4 540 546 A (GIESSEN ET AL) 10 September 1985 (1985-09-10) * column 5, line 39 - line 47 *	1-10	
			TECHNICAL FIELDS SEARCHED (IPC)
			C22C B22F B22D
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 5 April 2006	Examiner Schruers, H
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons</p> <p>&amp; : member of the same patent family, corresponding document</p>			

**ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.**

EP 04 25 3919

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Patent document cited in search report		Publication date		Patent family member(s)	Publication date
WO 8203809	A	11-11-1982	EP	0078272 A1	11-05-1983
US 4540546	A	10-09-1985	NONE		



ABSTRACT / ZUSAMMENFASSUNG / ABREGÉ

04253919.7

A method for forming a dispersion-strengthened material containing nanoparticles (12) that are uniformly dispersed in a matrix phase. The method includes adding nanoparticles (12) and a molten material (14) to a container to form a pool (16) within the container (10) and rotating the container (10) to create a convection vortex (20) in the pool. The convection vortex is sufficient to cause the nanoparticles to be incorporated into the molten material so as to yield a molten composite material, and further causes the molten composite material to be ejected from the container. The molten composite material is then cooled to form a solid composite body (24) comprising a uniform dispersion of the nanoparticles.